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(54) **Optical fiber coupler**

Faseroptischer Koppler

Coupleur à fibre optique

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Description

Background of the Invention

[Field of the Invention]

The present invention concerns optical fiber couplers employed in communication systems.

[Prior Art]

In one type of optical fiber coupler known in the art, two or more fibers are aligned side by side in a plane and thermally fused and elongated, thereby forming a fused-elongated region.

In the fused-elongated region thus formed, the diameter of each component optical fiber is reduced, as is the diameter of the core of each fiber. To the extent that diameter of the cores of the optical fibers are reduced, a proportionately larger fraction of the light propagated therein leaks through the clad which surrounds the core of each fiber. Also, to the extent that the component optical fibers are drawn out and thereby elongated, the distance between the cores of adjacent optical fibers is reduced, and due to this fact, the coupling between the propagated modes of the individual fibers becomes extremely great. In this way, the light signal carried by one fiber branches and is thus caused to be multiplexed over two or more optical fibers.

However, the above described optical fiber coupling technique has the following shortcomings:

1. When conventional quartz glass single mode optical fiber is used to form the optical fiber coupler, because the properties of the material are such that very little light energy is lost through the lateral surface of the fiber, the fused-elongated region must be quite long in order to sufficiently achieve optical coupling. Further, in order to form a fused-elongated region of sufficient length, the resulting diameters of the component optical fibers in the fused-elongated region end up being considerably reduced. For example, starting with quartz optical fibers having an outer diameter of 125 μm, it is possible that in the fused-elongated region of the resulting coupler, the fibers have a final outer diameter of on the order of 20 μm. Because of this effect, even a relatively small curvature in the optical fiber results in light leaking through the side of the fiber to the exterior with loss in light energy. With a larger amount of bending in the optical fiber, the bending losses become significant.

2. When forming the fused-elongated region, if it is desired to limit the amount of elongation and still achieve the desired degree of optical coupling, the length of the fused region must be considerable. Thus even though the elongation of the optical fiber has been limite[illegible]n a case, the coupler ends up being quite long.

Accordingly, in answer to applications calling for miniaturization, such an optical fiber coupler cannot be practically employed.

EP-A-0093460 relates to a method of manufacturing a fibre-optical coupling element, comprising fusing two monomode fibers, the fiber core of which are made of core glass the American softening temperature of which is at least 8°C higher than that of the cladding glass, the fibers being heated to a temperature lying between 520 and 560°C.

Summary of the Invention

In answer to the above described difficulties, it is an object of the present invention to provide an optical fiber coupler that can be employed in applications calling for miniaturization.

The present invention provides an optical fiber coupler obtainable by aligning side by side a section of each of two or more of component optical fibers, the coating material having been removed from said section thereby exposing the clad, mutually thermally fusing the exposed clad of adjacent optical fibers, after which the fused region is drawn out, thereby forming a fused-elongated region which constitutes the optical fiber coupler, optical fiber material being used in which the softening temperature of the core is higher than that of the clad, and further, for the drawing out of the mutually fused sections, the tension employed is such that by virtue of remaining stress, the refractive index of the core is reduced.

By so forming the optical fiber coupler, it is possible to reduce the difference in refractive index between the core and the clad, widen the mode power distribution, and thereby achieve optical coupling between adjacent optical fibers. Furthermore, because the amount of elongation or drawing of the fibers which is carried out after fusing the fibers need not be extreme while still achieving adequate optical coupling, it is thereby possible to improve the mechanical strength of the fused-elongated region. Moreover, because the amount of drawing of the component fibers after fusing and hence reduction in the diameters of their respective cores is limited, it is possible to create optical fiber couplers with low optical losses. By limiting the formation of curvature in the couplers, losses can be further lessened.

Brief Description of the Drawings

Fig. 1 is a side view of the optical fiber coupler of the first preferred embodiment of the present invention.

Fig.2 is a graph illustrating the relationship between the relative difference of the refractive index for the core and that for the clad and the tension applied during elongation for the optical fiber employed in the optical fiber

coupler shown in Fig. 1.

Figs. 3 through 5 are views of key points in the graph of Fig. 2 in which the relationship between the relative difference of the refractive index for the core and that for the clad and the tension applied during elongation is expressed in terms of the distribution of refractive index for the optical fiber.

Figs. 6 and 7 are illustrations of the power distribution in a fused section and a fused-elongated section respectively in an optical fiber coupler.

Fig. 8 is a side view of the optical fiber coupler of the second preferred embodiment of the present invention.

Fig. 9. is a side view of the optical fiber coupler of the third preferred embodiment of the present invention.

Fig. 10 is a side view of the optical fiber coupler of the fourth preferred embodiment of the present invention.

Figs. 11 and 12 are diagrams illustrating the dependance of degree of optical coupling on wavelength for the optical fiber couplers shown in Figs. 8 and 9 .

Detailed Description of the Preferred Embodiments

[First Preferred Embodiment]

In the following section, the first preferred embodiment of the present invention will be described with reference to Fig. 1.

The optical fiber coupler 21 of the present embodiment as shown in Fig. 1 consists of a fused-elongated region 25 formed by thermally fusing the clad from a section of each of two component optical fibers 24 and then drawing out the fused section, both of the optical fibers 24 being such that the softening temperature of the core 23 is higher than that of the clad 22. For the drawing out of the mutually fused sections, the tension employed is such that by virtue of remaining stress, the refractive index of the cores of the fused sections is reduced.

For the optical fibers 24 of the present embodiment, a suitable example is optical fiber material having a core 23 of essentially pure quartz (SiO_2) and a clad 22 containing added fluorine to thereby cause the clad to have a lower refractive index than the core. With this kind of optical fiber 24, at high temperatures the viscosity coefficient of the core 23 and that of the clad 22 differ by an order of magnitude (the viscosity coefficient of the core 23 is higher). Because the viscosity coefficient of the clad 22 is lower, by appropriately choosing the temperature used during elongation of the fused sections so that only the clad 22 is in a moldable state, is possible to impose a degree of elastic strain only in the core 23 which is controllable by the amount of tension applied during elongation. By virtue of the elastic strain imposed on the core 23, due to the strain dependant optical properties of the core material, the refractive index of the core 23 is decreased, while that of the clad 22 is not effected.

In Fig. 2 a graph is shown which demonstrates the relationship between the amount of tension applied during elongation of the heated optical fiber 24 and the lowering of the refractive index difference by decreasing the refractive index of the core material. For the graph of Fig. 2, an optical fiber material was used having a core diameter of 11 µm and a clad outer diameter of 125 µm. As is clear from Fig. 2, as the amount of tension applied during elongation of the optical fiber 24 is increased, the refractive index difference between the core and clad decreases.

In Figs. 3 through 5, the refractive index distribution is shown for the optical fiber 24. As shown in these drawings, for the single mode optical fiber 24, as the refractive index of the core (the upward projecting central portion of each drawing) decreases, and hence the refractive index difference for the optical fiber 24, the power distribution (P) of the propagation mode becomes wider and shorter, and is essentially shifted peripherally. Thus, by virtue of the effect of elongation on the refractive index difference and hence on the power distribution of the propagation mode with the optical fiber 24 of the present embodiment, a suitably wide mode diameter and hence good optical coupling can be achieved, which in the case of the optical fibers employed in prior art optical fiber couplers, would have required considerably more elongation and reduction in the core diameter.

In Figs. 6 and 7, the power distribution for the fused-elongated region 25 of the optical fiber coupler 21 of the present embodiment is schematically illustrated. Fig. 6 is the power distribution for the fused optical fibers 24 prior to elongation and Fig. 7 is the power distribution for the fused-elongated optical fibers 24 which constitute the fused-elongated region 25 of the optical fiber coupler 21. As is clear from Fig. 6 , there is no overlapping of the power distributions of the two component optical fibers 24 and hence no optical coupling can occur. In the case of the fused, and furthermore elongated optical fibers 24 shown in Fig. 7 , there is good overlap of the power distributions emanating from the somewhat narrowed cores 23 in the fused-elongated region 25 so that the optical signal of one of the component optical fibers 24 can seep into and hence couple with the adjacent optical fiber.

As described above, in the optical fiber coupler 21 of the present embodiment, adequate optical coupling can be achieved without extreme elongation of the component optical fibers 24, and hence extreme reduction in the diameters of their cores. Accordingly, the mechanical strength of the optical fiber coupler 21 can be improved. Further, optical losses caused by bending of the optical fiber coupler 21 can be lessened.

[First Experimental Example]

Using two optical fibers 24, each having a core diameter of 10 µm, a clad external diameter of 125 µm, a refractive index difference prior to elongation of 0.3 %,

a core of pure quartz, [redacted] incorporating added fluorine, a 100 μm portio[redacted]ach were aligned side by side and thermally fused using a sufficiently high temperature so as to form a roughly cylindrical fused portion which was then drawn out to produce a fused region having a diameter of approximately 125 μm.

Next, the fused region formed as described above was heated to a relatively low temperature on the order of 1300° C and drawn out at a pulling tension of 50 g, whereby the diameter of the fused section was reduced by about 10 %. Finally, while the above described pulling tension was maintained, the heating temperature was rapidly lowered to thereby produce an optical fiber coupler 21 the same as that of the fourth preferred embodiment as shown in Fig. 1 By means of the above described procedure, a suitable degree of optical coupling between the two component optical fibers 24 can be achieved. The optical fiber coupler 21 thereby obtained had a mechanical strength close to that of the component optical fibers 24. Furthermore, optical losses for the obtained optical fiber coupler 24 were low at about 0.2 dB.

In the present experimental example, the length of the section of initially fused optical fibers 24 was 100 μm, however, this length can be up to 1 to 2 mm for the same type of optical fiber coupler 21. As an example, an optical fiber coupler 21 was fabricated in which the length of the section of initially fused optical fibers 24 was 1 mm with all other conditions being the same. The optical fiber coupler 21 thereby produced demonstrated optical losses of 0.3 dB.

[Second Preferred Embodiment]

In the following section, the second preferred embodiment of the present invention will be described with reference to Fig. 8.

The optical fiber coupler 26 of the present embodiment as shown in Fig. 8 consists of a twisted fused-elongated region 27 formed by thermally fusing the clad from a section of each of two component optical fibers 24 identical to those of the above first preferred embodiment and then drawing out the fused section while twisting the pair of optical fibers 24. For the drawing out and twisting of the mutually fused sections, the tension employed is such that by virtue of remaining stress, the refractive index of the cores of the fused sections is reduced.

With the optical fiber coupler 26 of the present embodiment, as was the case with the optical fiber coupler 21 of the first preferred embodiment shown in Fig. 1, essentially by decreasing the refractive index difference between the core and clad and thereby broadening the mode power distribution, suitable optical coupling between the fused sections of optical fiber 24 can be achieved. Accordingly, without extremely reducing the diameter of the fused-elongated region 27, adequate optical coupling is possible. Thus, the mechanical strength of the opti[redacted]oupler 26 can be improved. Further, optical losses caused by bending of the optical fiber coupler 26 can be lessened.

[Second Experimental Example]

Using two optical fibers 24, each having a core diameter of 10 μm, a clad external diameter of 125 μm, a refractive index difference prior to elongation of 0.3 %, a core of pure quartz, and a clad incorporating added fluorine, a 100 μm portion of each were aligned side by side and thermally fused using a sufficiently high temperature so as to form a roughly cylindrical fused portion which was then drawn out while twisting three full turns to produce a fused region having a diameter of approximately 80 μm.

Next, the fused region formed as described above was heated to a relatively low temperature on the order of 1300° C and drawn out at a tension of 50 g, whereby the diameter of the fused section was reduced by about 10 %. Finally, while the above described pulling tension was maintained, the heating temperature was rapidly lowered to thereby produce an optical fiber coupler 26 the same as that of the second preferred embodiment as shown in Fig. 8. By means of the above described procedure, a suitable degree of optical coupling between the two component optical fibers 24 can be achieved. The optical fiber coupler 26 thereby obtained had a mechanical strength close to that of the component optical fibers 24. Furthermore, insertion losses for the obtained optical fiber coupler 24 were low at about 0.2 dB.

In the present experimental example, the length of the section of initially fused optical fibers 24 was 100 μm, however, this length can be up to 1 to 2 mm for the same type of optical fiber coupler 26. As an example, an optical fiber coupler 26 was fabricated in which the length of the section of initially fused optical fibers 24 was 1 mm with all other conditions being the same. The optical fiber coupler 26 thereby produced demonstrated insertion losses of 0.3 dB.

[Third Preferred Embodiment]

In the following section, the third preferred embodiment of the present invention will be described with reference to Fig. 9.

The optical fiber coupler 28 of the present embodiment as shown in Fig. 9 consists of a fused-elongated region 30 formed by thermally fusing the clad from a section of each of two component optical fibers 29 having a quartz glass core of which the refractive index was reduced 0.1 % or less by the addition of fluorine, and a quartz glass clad of which the refractive index was adjusted to a level lower than that of the core by the addition of fluorine, and then drawing out the fused section. For the drawing out of the mutually fused sections, the tension employed is such that by virtue of remaining

stress, the refractive index of the cores of the fused sections is reduced. The reason for using a glass fiber for which the refractive index of the core is reduced 0.1 % or less as described above is to facilitate the formation of an optical fiber coupler 28 having a suitable refractive index difference between the core and clad.

Because the component optical fibers 29 employed in the present preferred embodiment can have a core-clad refractive index difference even lower than that of the component optical fibers 24 employed in the first and second preferred embodiments, effective optical coupling between the fused sections of optical fiber 29 can be achieved with even less elongation and hence diameter reduction. Accordingly, the mechanical strength of the optical fiber coupler 28 can be further improved and insertion losses caused by bending of the optical fiber coupler 28 can be further lessened.

[Third Experimental Example]

Using two optical fibers 29, each having a core diameter of 10 µm, a clad external diameter of 125 µm, a refractive index difference prior to elongation of 0.32 %, a core of quartz incorporating added fluorine (sufficient fluorine is added so that the refractive index of the core is reduced 0.05 %), and a quartz clad incorporating added fluorine, 100 µm portions from each of the component optical fibers 29 were aligned side by side and thermally fused using a sufficiently high temperature so as to form a roughly cylindrical fused portion which was then drawn out produce a fused region having a diameter of approximately 125 µm.

Next, the fused region formed as described above was heated to a relatively low temperature on the order of 1300° C and drawn out at a pulling tension of 50 g, whereby the diameter of the fused section was reduced by about 10 %. Finally, while the above described pulling tension was maintained, the heating temperature was rapidly lowered to thereby produce an optical fiber coupler 28 the same as that of the third preferred embodiment as shown in Fig. 9. By means of the above described procedure, a suitable degree of optical coupling between the two component optical fibers 29 can be achieved. The degree of optical coupling for the optical fiber coupler 28 thereby obtained was then measured and it was found that 51 % optical coupling was obtained between port 2E and port 2G shown in Fig.9 , 49 % between port 2E and port 2H, 49 % optical coupling was obtained between port 2F and port 2G, and 51 % optical coupling was obtained between port 2F and port 2H. Furthermore, optical losses for the obtained optical fiber coupler 28 were low at about 0.2 dB.

In the present experimental example, the length of the section of initially fused optical fibers 29 was 100 µm, however, this length can be up to 1 to 2 mm for the same type of optical fiber coupler 28. As an example, an optical fiber coupler 28 was fabricated in which the length of the section of initially fused optical fibers 29 was 1 mm with all other conditions being the same. The optical fiber coupler 28 thereby produced demonstrated losses of 0.3 dB.

[Fourth Preferred Embodiment]

In the following section, the fourth preferred embodiment of the present invention will be described with reference to Fig. 10.

The optical fiber coupler 31 of the present embodiment as shown in Fig. 10 consists of a fused-elongated region 33 formed by lining up and thermally fusing the clad from a section of each of two component optical fibers, an optical fiber 29 identical to that employed in the above third preferred embodiment, and an optical fiber 32 having a core of a lesser diameter than that of the optical fiber 29, and then drawing out the fused section. For the drawing out of the mutually fused sections, the tension employed is such that by virtue of remaining stress, the refractive index of the cores of the fused sections is reduced.

For the optical fiber coupler 31 of the present embodiment, the phase constant is different for each of the component optical fibers 29, 32. For this reason, optical coupling in the optical fiber coupler 31 is largely wavelength independent, as demonstrated by the fairly flat curve in Fig.11 which shows the degree of optical coupling between port 2I and 2L as a function of wavelength of the light for the optical fiber coupler 31 shown in Fig. 10.

In contrast, for the case of the previously described optical fiber couplers 21, 26 and 28, shown in Figs. 1, 8 and 9 respectively, which are fabricated from two identical optical fibers, the coupling ratio differs with changing wavelength of the transmitted light, with virtually 100 % coupling occurring at certain specific wavelengths of the transmitted light. As shown in Fig. 12, when an optical signal containing two wavelength components, was input at port 2E of the optical fiber coupler 28 shown in Fig. 9, it was found that the optical signal was separated into its two components, one emitted from port 2G and one emitted from port 2H. Thus, in distinction to the optical fiber coupler 31 of the present embodiment, those optical fiber couplers employing two identical optical fibers can be used as a selective wavelength splitter type optical fiber coupler.

In the optical fiber coupler 31 of the present preferred embodiment, because the phase constant is different for each of the component optical fibers 29, 32, optical coupling in the optical fiber coupler 31 is largely wavelength independent. Accordingly, the optical fiber coupler 31 can be used over a wide range of wavelengths as a wavelength independent optical fiber coupler (wide band-pass type optical fiber coupler).

[Fourth Experimental Example]

Using an optical fibers 29 having a core diameter of

10 µm, a clad external [redacted] 125 µm, a refractive index difference prior to [redacted] of 0.32 %, a core of quartz incorporating added fluorine, and a quartz clad incorporating added fluorine, and an optical fiber 32 having a core diameter of 9 µm, a clad external diameter of 125 µm, a refractive index difference prior to elongation of 0.32 %, a core of quartz incorporating added fluorine, and a quartz clad incorporating added fluorine, 100 µm portions from each of the component optical fibers 29 were aligned side by side and thermally fused using a sufficiently high temperature so as to form a roughly cylindrical fused portion which was then drawn out produce a fused region having a diameter of approximately 125 µm.

Next, the fused region formed as described above was heated to a relatively low temperature on the order of 1300° C and drawn out at a tension of 50 g, whereby the diameter of the fused section was reduced by about 10 %. Finally, while the above described pulling tension was maintained, the heating temperature was rapidly lowered to thereby produce an optical fiber coupler 31 the same as that of the fourth preferred embodiment as shown in Fig. 10.

In the present experimental example, the length of the section of initially fused optical fibers 29, 32 was 100 µm, however, this length can be up to 1 to 2 mm for the same type of optical fiber coupler 31. As an example, an optical fiber coupler 31 was fabricated in which the length of the section of initially fused optical fibers 29 was 1 mm with all other conditions being the same. The optical fiber coupler 31 thereby produced demonstrated optical losses of 0.3 dB.

The various examples of the present invention presented in the above preferred embodiments are merely examples and are in no way to be construed as limiting the present invention. It is possible, for example, to employ three or more optical fibers in the optical fiber coupler of the present invention with acceptable results. It should be understood that the optical fiber coupler of the present invention includes all forms encompassed by the appended claims.

Claims

1. An optical fiber coupler obtainable by aligning side by side a section of each of two or more component optical fibers, the coating material having been removed from each said section thereby exposing the clad, fusing the exposed clads together to form a fused section and then elongating the fused section to form a fused-elongated region, in which the component optical fibers are optical fibers of which the softening temperature of the core is higher than that of the clad, and in which for said elongating of the fused section the tension employed is such that by virtue of remaining stress, the refractive index of the cores of said optical fibers is reduced.

2. An optical fiber [redacted] in accordance with Claim 1 wherein the fused elongated region is twisted during elongation to form a twisted fused-elongated region.

3. An optical fiber coupler in accordance with either of Claims 1 and 2 of which the cores of said two or more component optical fibers are dopant free quartz glass, and of which the clads of said two or more component optical fibers are quartz glass of which the refractive index has been adjusted by the addition of at least one additive selected from the group including fluorine and boron.

4. An optical fiber coupler in accordance with either of Claims 1 and2 of which the cores of said two or more component optical fibers are quartz glass containing a dopant such that the refractive index has been altered by as much as 0.1 %, and of which the clads of said two or more component optical fibers are quartz glass of which the refractive index has been adjusted by the addition of at least one additive selected from the group including fluorine and boron.

5. An optical fiber coupler in accordance with any of claims 1 to 4, in which said two or more component optical fibers include optical fibers of at least two different diameters.

Patentansprüche

1. Faseroptischer Koppler, der geschaffen werden kann durch die Ausrichtung eines Abschnitts jeder von zwei oder mehreren optischen Komponenten-Fasern nebeneinander, wobei das Primärbeschichtungsmaterial von jedem dieser Abschnitte entfernt worden ist, um so den Mantel freizulegen, die thermische Verschmelzung der freigelegten Mäntel miteinander, um einen verschmolzenen Abschnitt zu bilden, und die anschließende Längung des verschmolzenen Abschnitts, um einen verschmolzenen Längsbereich zu bilden, bei dem die optischen Komponenten-Fasern optische Fasern sind, bei denen die Erweichungstemperatur des Kerns höher als die des Mantels ist und bei denen zur Längung des verschmolzenen Abschnitts ein solcher Zug angewandt wird, daß auf Grund der verbleibenden mechanischen Spannung der Brechungsindex der Kerne der optischen Fasern verringert wird.

2. Faseroptischer Koppler nach Anspruch 1, bei dem der verschmolzene Längsbereich während der Längung verdrillt wird, um einen verdrillten verschmolzenen Längsbereich zu bilden.

3. Faseroptischer Koppler nach einem der Ansprüche

1 oder 2, bei dem [redacted] der zwei oder mehr optischen Kompone[redacted]-Fasern aus dotierungsstoff-freiem Quarzglas sind und bei dem die Mäntel der zwei oder mehr optischen Komponenten-Fasern aus Quarzglas sind, dessen Brechungsindex durch das Hinzufügen von wenigstens einem Zusatz abgestimmt worden ist, der aus der Gruppe ausgewählt wurde, die Fluor und Bor umfaßt.

4. Faseroptischer Koppler nach einem der Ansprüche 1 oder 2, bei dem die Kerne der zwei oder mehr optischen Komponenten-Fasern aus Quarzglas sind, das einen solchen Dotierungsstoff enthält, daß der Brechungsindex um bis zu 0,1 % geändert worden ist, und bei dem die Mäntel der zwei oder mehr optischen Komponenten-Fasern aus Quarzglas sind, dessen Brechungsindex durch das Hinzufügen von wenigstens einem Zusatz abgestimmt worden ist, der aus der Gruppe ausgewählt wurde, die Fluor und Bor umfaßt.

5. Faseroptischer Koppler nach einem der Ansprüche 1 bis 4, bei dem die zwei oder mehr optischen Komponenten-Fasern optische Fasern mit wenigstens zwei unterschiedlichen Durchmessern einschließen.

Revendications

1. Coupleur à fibres optiques pouvant être obtenu en alignant côte à côte une section de chacune des deux ou plusieurs fibres optiques constituantes, le matériau de revêtement ayant été enlevé de chacune desdites sections, de façon à dégager la gaine, en fondant les gaines dégagées l'une à l'autre pour former une section fondue, et en allongeant ensuite la section fondue pour former une région fondue et allongée, dans lequel les fibres optiques constituantes sont des fibres optiques dont la température de ramollissement du coeur est supérieure à celle de la gaine, et dans lequel, pour ledit allongement de la section fondue, la tension utilisée est telle que, par suite de la contrainte résiduelle, l'indice de réfraction des coeurs desdites fibres optiques est diminué.

2. Coupleur à fibres optiques selon la revendication 1, dans lequel la région fondue et allongée est tordue pendant l'allongement pour former une région fondue, allongée et tordue.

3. Coupleur à fibres optiques selon l'une quelconque des revendications 1 ou 2, dont les coeurs desdites deux ou plusieurs fibres optiques constituantes sont en verre de quartz exempt de dopant et dont les gaines desdites deux ou plusieurs fibres optiques constituantes sont en verre de quartz, dont l'indice de réfr[redacted]été réglé par l'addition d'au moins un additif choisi dans le groupe comprenant le fluor et le bore;

4. Coupleur à fibres optiques selon l'une quelconque des revendications 1 ou 2, dont les coeurs desdites deux ou plusieurs fibres optiques constituantes sont en verre de quartz contenant un dopant tel que l'indice de réfraction a été modifié jusqu'à 0,1% et dont les gaines desdites deux ou plusieurs fibres optiques constituantes sont en verre de quartz, dont l'indice de réfraction a été réglé par l'addition d'au moins un additif choisi dans le groupe comprenant le fluor et le bore.

5. Coupleur à fibres optiques selon l'une quelconque des revendications 1 à 4, dans lequel lesdites deux ou plusieurs fibres optiques constituantes comprennent des fibres optiques d'au moins deux diamètres différents.

FIG.1

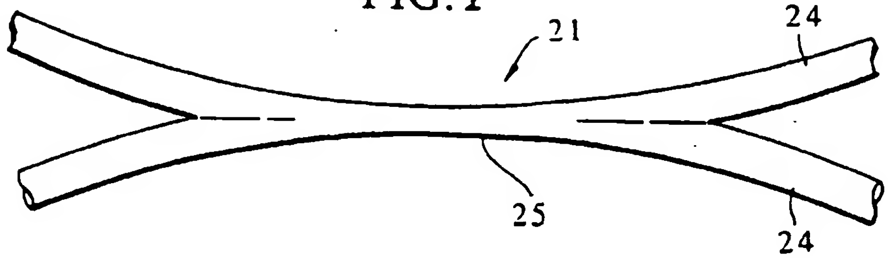


FIG.2

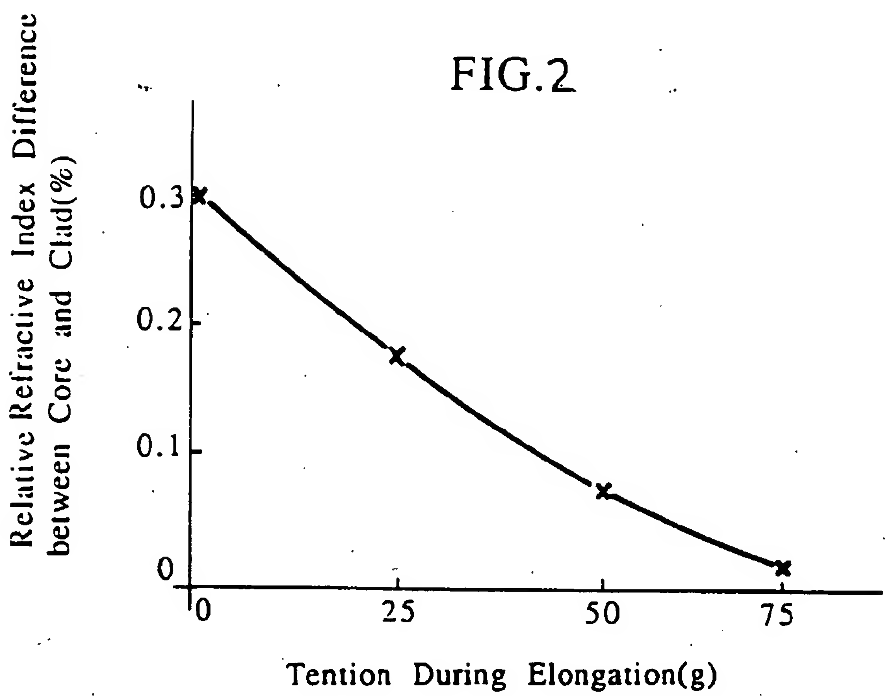


FIG.3

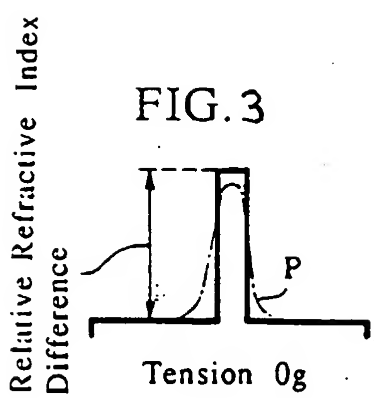


FIG.4

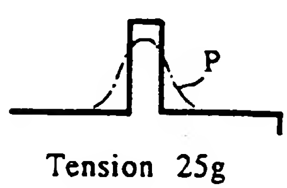


FIG.5

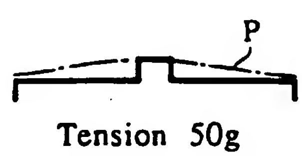


FIG. 6

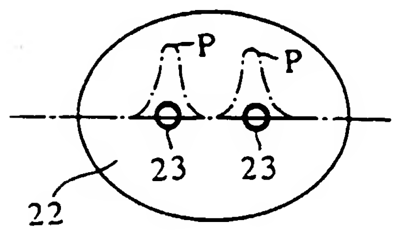


FIG. 7

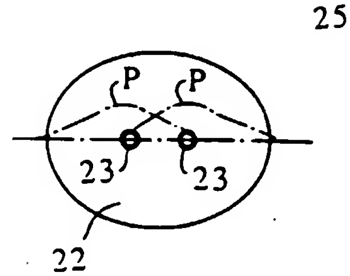


FIG. 8

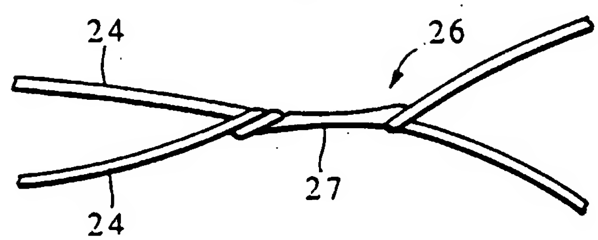


FIG. 9

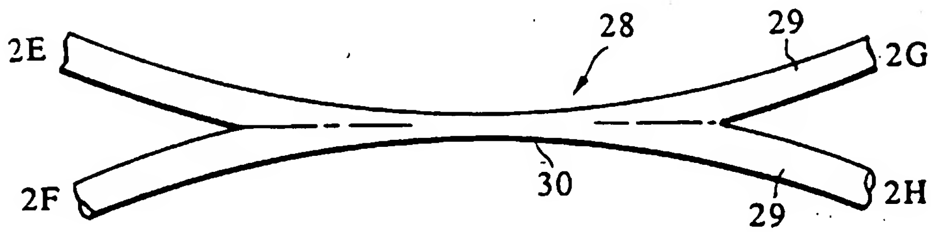


FIG. 10

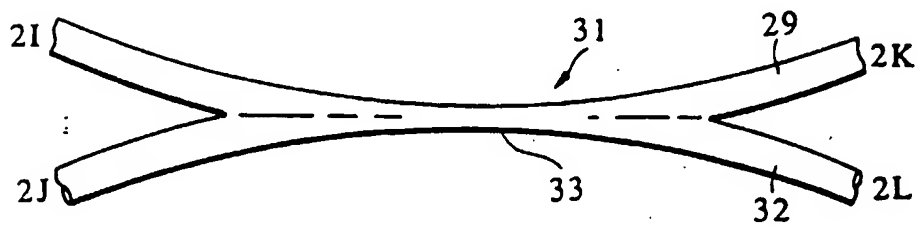


FIG. 11

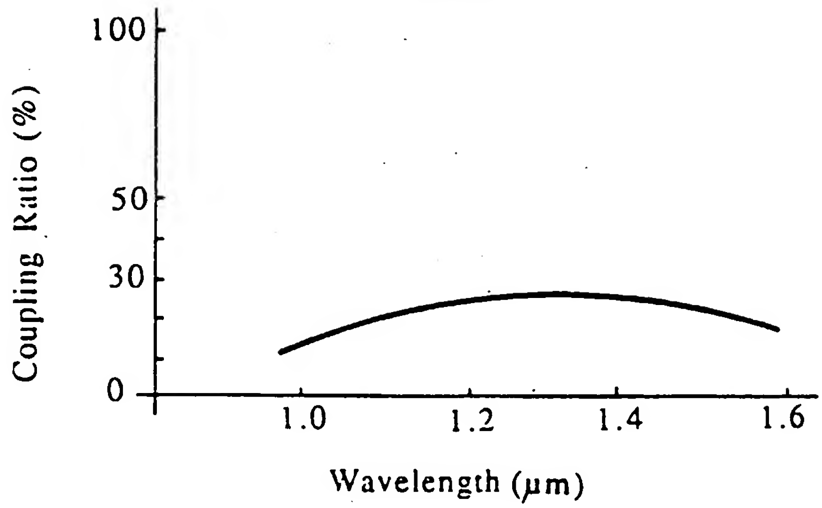
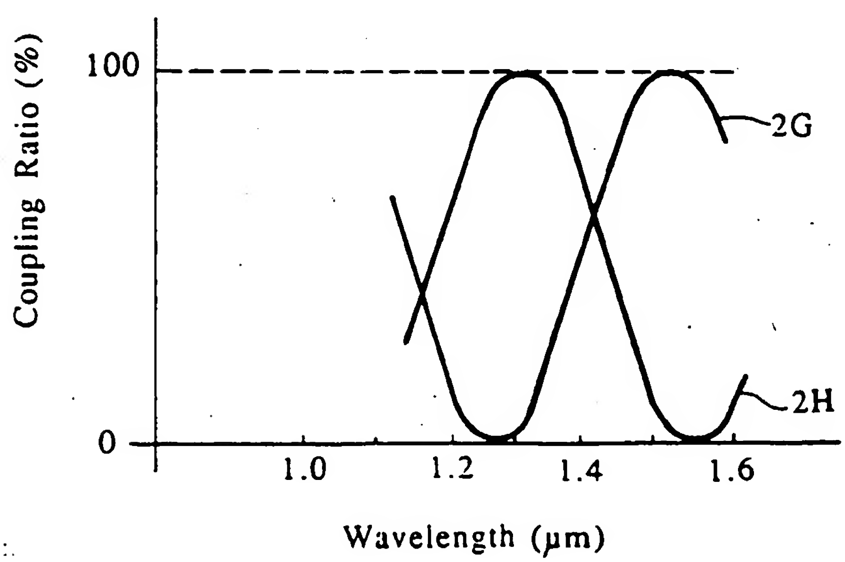

100
50
30
0
Coupling Ratio (%)
1.0
1.2
1.4
1.6
Wavelength (μm)

FIG. 12


100
0
Coupling Ratio (%)
2G
2H
1.0
1.2
1.4
1.6
Wavelength (μm)